Faculty of Health, Engineering and Sciences

Optimising nutrient extraction from chicken manure and compost

For the award of

DOCTOR OF PHILOSOPHY

A dissertation submitted by

Abdalhakim Mohamed A. Ksheem

2014

To my Mother and Father,

To my Sisters Salma and Ahlam,

To my Brothers Khaled, Adel, Mahmoud and Neserdeen,

To my Wife Marwa,

To my Children Safa and Daina,

To each who taught me goodness and humanity,

To each who instilled in me the meaning of hope and humanitarian highness,

To each who helped me,

I dedicate this work.

Abdalhakim Mohamed A. Ksheem

USQ, Queensland, Australia.

Abstract

The global production of chicken manure is estimated to be 457 million tonnes per year. Chicken manure contains most nutrients that could be applied as a fertiliser to plants. Chicken manure has a high salinity level, high nitrogen and phosphorus content, low C/N ratio and contains pathogens. Hence, the disposal of chicken manure requires appropriate management to avoid environmental contamination. The main disposal practices are direct application to agricultural lands or composting. However, both of these methods require a high standard of management. This research investigates strategies for optimising nutrient extraction by leaching chicken waste. If the leachate can be extracted and treated effectively, then it may be applied to crops using an irrigation system where the rate and time of application are more readily controlled.

There are a range of methods used to extract soluble nutrients from animal manure at different scales. The main nutrient extraction methods produce either a manure leachate or manure tea. However, the quality (both nutrient and pathogen levels) of the leachate or tea is a function of the waste material properties and the extraction method used. Hence, the aim of this research was to identify strategies which optimised the extraction of the soluble nutrients from chicken manure or compost.

Fresh chicken manure and compost (ranging in age from 1 to 18 weeks) was packed into small columns which were subsequently leached. The leachate extracted from fresh manure and week 1 compost was found to contain higher concentrations of soluble nutrients than leachate derived from the week 6 and 18 composts. However, the leachate from the fresh manure also contained high levels of sodium and the leachate from both fresh manure and the young composts contained pathogens. On the other hand, leachate extracted from the older composts (≥4 weeks old) was free of pathogens.

Further column studies were conducted to (a) evaluate the effect of column length and packing density on the nutrient extraction, (b) identify strategies for eliminating pathogens in the leachate and (c) evaluate the effect of increasing the hydraulic pressure in the extraction process. In general, the concentration of soluble nutrients in the leachate was found to increase with both column length and packing density. To evaluate the sterilisation options, a range of treatments (hot water, acetic acid and hydrogen peroxide) were applied during leaching and different treatments (acetic acid, hydrogen peroxide, heating and ozone) were applied to the extracted leachate. The most effective treatments were found to involve leaching with hot water (although the concentration of soluble nutrients was greatly reduced) or applying ozone to the extracted leachate (which did not affect the nutrient levels). While the application of a low hydraulic pressure during leaching reduced the time required to extract nutrients the concentration of soluble nutrients per unit volume of leachate was reduced due to a reduced contact time.

This work has identified the effect of the waste material properties and extraction methodology on nutrients in the leachate. However, further work is required to (a) better understand the optimal column length to packing density ratio and the extraction pressure appropriate for specific waste materials, (b) evaluate strategies to mitigate the potential effect of high sodium levels found in the leachate, (c) evaluate the efficacy of

nutrient extraction improvements, including the use of a recirculating leaching system, and (d) refine the nutrient extraction system design for commercial scale use.

Certification of Dissertation

I certify that the ideas, experimental work, analyses, results, and conclusions reported in this dissertation are my own work, except where otherwise specified acknowledged. I further certify that this work is original and has not been previously submitted for any another award, except where otherwise acknowledged.

Endorsement:

Abdalhakim Mohamed A. Ksheem **Date**

Professor Steven Raine, Principal Supervisor **Date**

Dr John McLean Bennett, Co- Supervisor **Date**

Acknowledgment

I wish to express my thanks to those people who have supported and helped me during my study. Firstly, my sincere thanks to my supervisors Professor Steven Raine and Dr John McLean Bennett for supervising me and for their patience and guidance during my study. I sincerely thank them for their support and encouragement of me, especial during the bad circumstances that my country Libya faced during 2011. Also, I thank them for their technical assistance and expert advice.

I wish to greatly acknowledge the support of Tripoli University, the Libyan Government, for providing funding for a full scholarship and the National Centre of Engineering Agriculture (NCEA) for providing me further operational funding to support my research.

A special thanks to the NCEA staff for their support of me, I am thankful to Dr Pam Pittaway for her valuable discussions and assistance regarding composting and chicken manure analysis; and, to both Dr Dio Antille and Dr Lindsay Henderson for their help in undertaking some editing. I also appreciate the support provided by Professor Dan Sullivan at the Oregon State University and Professor Abdullah Sasi at The University of Tripoli for their valuable advice.

Also, I am thankful to the lovely staff in the Faculty of Health, Engineering and Sciences, USQ. A special thanks to Dr Friederike Eberhard and Mr Raed Ahmed for their support in the waste water Laboratory. Also, I am thankful to all my friends and colleagues at USQ, especially Jamal Fernana and Emohamed Maryol for their encouragement and support. Finally I would like to thank my father, mother, brothers, wife and children for their encouragement and support during my study.

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrometer
ANOVA	Analysis of variance
C	Carbon
C/N	Carbon to nitrogen ratio
Ca	Calcium
^{o}C	Degree Celsius
CO_2	Carbon dioxide
Cl	Chloride
CROSS	Cation Ratio of Soil Stability
DM	Dry mass
$dS\ m^{-1}$	Decisiemens per meter
EC	Electrical Conductivity
FAO	Food and Agriculture Organisation
K	Potassium
KCl	Potassium Chloride
Ksat	Saturated Hydraulic conductivity
LSD	Least Significant Difference
Mg	Magnesium
N	Nitrogen
Na	Sodium
NO_3	Nitrate
NO_2	Nitrite
P	Phosphorus
SOM	Soil Organic Matter
USDA	United States Department of Agriculture